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done IX, 97

Transference of Nematodes (Mononchs) from Place to Place for Economic Purposes.

[*The following article from "Science," June* 25, 1920, *by Dr. N. A. Cobb is of interest because it advocates the handling of nematode problems on the same line as we have handled our insect problems for some years. The writer discussed this subject with Dr. Cobb three years ago in Washington, and we agreed that the Hawaiian Islands offered as good a field for this experiment as they do for similar ones in entomology. Unfortunately, we have not the same knowledge of the systematic aspects of our nematodes as we have of our insects, and so the problem could not at present be handled with the same confidence. To enable us to work with equal confidence we should have to make a fairly good survey of the nematodes of the Islands.*

The technique necessary to handle these animals is more delicate than with insects, and precautions to keep out harmful nematodes would have to be taken. But both these points could be overcome. Where heavy loss of crops is due to nematodes the question is worthy of serious attention.—F.M.]

Speaking generally, it is now beyond question that many soil-inhabiting mononchs feed more particularly on other nemas. However, they never follow these latter into plant roots, except in the case of open root cavities fairly readily accessible. They do not enter living plant tissues in pursuit of their prey. It follows that the good they do is in devouring the larvae and young of injurious nemas at such times as the latter are accessible either in the soil or in open cavities in the roots of plants.

In transferring mononchs from place to place with a view to making use of them in combating injurious nemas, the first requisite is a supply of mononchs. Such a supply may be obtained from soils in which the mononchs are numerous, and although we have comparatively little experience to guide us, yet it is now demonstrated that supplies of mononchs existing under these conditions are avail-

able. Thus far these supplies have been discovered more or less by accident; the cases, however, are numerous enough to establish the belief that special search will lead to the discovery of a sufficient number of these original sources of mononchs to furnish an adequate supply for trial.

The methods for collecting the mononchs, and transferring them, once they have been found, have been sufficiently elaborated for practical purposes, and published.

In transferring the mononchs to new situations, it is, of course, best to pay careful attention to the relative physical and biological conditions of the two habitats—the soil from which they are transferred and that to which they are transferred. The physical and biological conditions of the two habitats should be such as to insure the persistence of the mononchs after they have been transferred from the old to the new habitat. If the climatic and soil conditions of the new habitat closely resemble those of the old habitat, there is every reason to suppose that the mononchs will survive and flourish if there is a supply of suitable food.

The practical details may be illustrated by a hypothetical example. Suppose a region in Holland having a sandy soil has distributed in it as a plant pest the devastating nema, *Tylenchus dipsaci,* which, though more or less prevalent, is not doing very serious damage because held in check by mononchs. Suppose the existence of another region, like that in the vicinity of Bellingham, State of Washington, U. S. A., having a soil and climate similar to that of the district in Holland just mentioned, and suffering more or less severely from the ravages of *Tylenchus dipsaci* because this nema is not sufficiently held in check by any natural force. We may suppose that in this latter case *dipsaci* has been introduced at Bellingham without the enemies and parasites that hold it in check in the first-mentioned place. The mononchs found in the soil of the Holland district feeding upon *Tylenchus dipsaci* are collected and transported to Bellingham and introduced into the soil. There is good reason to suppose that under the new conditions, finding their food abundant, including the larvae and young of *Tylenchus dipsaci,* the mononchs will flourish and keep *Tylenchus dipsaci* in check.

If it be asked why injurious nemas are transferred from place to place without their enemies being transferred at the same time, the answer is that nemas injurious to plants are often transferred in the interior parts of plants imported in a living condition, and, as already indicated, the mononchs and other predatory nemas are less common in these situations than they are in the adjacent soil, which latter in the course of commerce often is removed from the roots and not shipped. One need only instance the case of bulbs and similar importations to see how much better chance the injurious parasitic nemas have of being imported than have those nemas which feed upon them. There is also reason to believe that sometimes the parasitic nemas infesting crops are more resistant to untoward conditions, e. g., dryness, than are the predaceous nemas.

We have at the present time arrived at a stage where logically the next step is to try out the introduction of promising species of mononchs. Efforts of this kind will necessarily be somewhat expensive, probably more expensive than the corresponding early efforts to introduce beneficial insects. There can be no doubt, however, that the enormous losses due to plant-infesting nemas fully

justify the expenditure of even large sums of money in an effort to apply this remedy, more particularly because the remedy, when successful, bids fair to be permanent and self-sustaining.

After long-continued and intensive studies I am thoroughly convinced that many of the practises evolved in the transfer of beneficial insects can, with appropriate modification, be applied to the nemas. At the present time the greatest drawback in the case of the nemas is the small number of people who are technically competent to make the necessary biological examinations. It is in this respect principally that their introduction will differ from that of the introduction of useful insects, for the nema problem is essentially a microscopic one. Though the collection of the nemas from the soil differs entirely from the collection of beneficial insects, the methods have already been brought to such a state that there are no insuperable obstacles.

The percentage of mononchs in miscellaneous collections of soil-inhabiting nemas taken from various situations is roughly indicated by the following figures based on the writer's examinations—in each case of from one thousand to several thousand specimens:

1. Miscellaneous collection from very small quantity of soil taken from the roots of 14 species of plants imported from Brazil, 6.5 per cent mononchs.
2. Sandy soil about the roots of astilbe and peony, Holland, 11.6 per cent mononchs.
3. Soil from cornfield in New Jersey in autumn, the prevailing genus was *Mononchus*.
4. Sand from Washington filter beds, 96 per cent mononchs.

N. A. Cobb.

U. S. Department of Agriculture.

Some Chemical Aspects of Soil Fertility.*

By Frank T. Dillingham.†

Soil fertility may be defined as the ability of a soil to produce and to maintain good crop yields. This ability of the soil to produce and to maintain good crop yields depends upon a number of factors which may be classed under three heads: (a) chemical, (b) biological, (c) physical. Soil fertility may also be defined as that condition of a soil which makes it productive. The elements of soil fertility are a full supply of available plant food, a suitable and continuous supply of moisture, and a good physical condition of the soil.

It is the purpose of this paper to consider some of the more important chemical and biological factors involved in soil fertility. It will be well first of all to present briefly a few of the commonly accepted ideas concerning the chemistry of soil formation, but in discussing the chemical agencies it is prac-

* A lecture presented at the University of Hawaii, Short Course for Plantation Men, October, 1920.

† University of Hawaii.

tically impossible to avoid mention of certain physical agencies in this connection because of the intimate relationship between the two types of forces.

Soils as we know them today have been and are being derived from rock materials on the surface of the earth. When in the molten state, our globe was surrounded by huge masses of water vapor which upon condensation descended in torrents upon the molten rock mass to be immediately converted into steam which rising into the air was again condensed into water, in turn to fall again upon the earth's surface. The ultimate effect of this action, repeated an infinite number of times, was to cool down the surface of the earth to such a point that various forms of life could appear. While this action was mainly physical, chemical changes undoubtedly occurred in the rock masses through solvent action of the water which must have held oxygen, carbon dioxide, oxides of nitrogen, and other gases in solution.

Bacteria were probably the first forms of life to appear. Investigation has shown that such organisms exert an important influence in aiding rock decomposition. It appears that these minute forms of life utilize carbon from atmospheric carbon dioxide as do higher plants, and also utilize ammonium carbonate forming organic matter from it and liberating nitric acid. These organisms are able to penetrate every little crevice produced by weathering agencies, and acting throughout long periods of time produce results of considerable geological importance. They act upon rock fragments, constantly reducing them to smaller and smaller sizes. Each fragment loosened from the rock mass is found covered with a film of organic matter, and the accumulation begun by these apparently insignificant forces is added to by the remains of plants of higher orders which come as soon as nutriment and standing room are provided.

After bacteria there appeared low forms of plant life such as lichens and mosses, which, growing upon the rock masses sent their tiny rootlets into every crevice seeking not merely foothold but food as well. Slight as such action was it promoted the disintegration of rock. The plants died and others grew upon their remains; thus there accumulated, often with extreme slowness, a thin layer of humus which retained moisture from rain bringing the rock under the influence of chemical action and also furnished small amounts of organic acids which acted as solvents. In the course of time enough soil accumulated to furnish standing room for larger and higher types of plant life which exercised even more powerful action. In case of rocks in a jointed condition, the roots of plants pushing downwards enlarge the crevices by virtue of their gain in bulk from day to day and thus furnish more ready access for moisture to hasten the disintegration.

The physical and chemical action of the roots of plants is enormous in the aggregate. The direct chemical action of this agency is said by some investigators to be due to organic acids exuded from the roots; the exact nature of these acids is not accurately known, but it is considered possible that a variety of organic acids exists in the rootlets of each species of plants. On the other hand many investigators hold that the corrosive effect of root action is due largely, if not wholly, to carbonic acid.*

The chemical action of water, especially in connection with the atmosphere as an agency in the formation of soils may be considered briefly under four heads:—(1) oxidation, (2) deoxidation, (3) hydration, and (4) solution. (1) Oxidation is noticeable only in rocks containing iron as sulphide, ferrous carbonate, or silicate Such an oxidation is often accompanied by an increase in bulk, so that even if nothing escapes by solution there may enter a powerful physical agency to aid in disintegration. As the oxidation continues the minerals become gradually decomposed and fall away into unrecognizable forms. (2) Deoxidation is less common than oxidation. Water containing small amounts of organic acids may reduce higher oxides to lower forms and change ferrous sulphates into sulphides, a process which probably takes place in marine muds. (3) Hydration usually accompanies oxidation and is an important agency in the disintegration of rock. This is particularly true in the case of micaseous sandstones and granitic rocks. Such a change, provided that it is not attended by a loss of constituents by solution or erosion, is often accompanied by an appreciable increase in bulk. In the transition of a granitic rock to arable soil it has been estimated that an increase in bulk amounting to 88% may take place. (4) The solvent action of water is probably the most important of its immediate effects. We must consider the action not of pure water, but of water containing various salts, acids, and gases which it has taken up in passing through the atmosphere and in filtering through the layer of organic matter and decomposition products which cover such a large portion of the surface of the land. The presence of these various substances in solution enormously increases the solvent action of water. Of all the mineral substances acted upon, limestones are the most easily affected, but it has been conclusively shown that all the ordinary rock forming minerals, silicates, oxides, and carbonates, are appreciably soluble in the water of rainfalls and at ordinary temperatures. Through the decomposition of iron pyrites there may be formed free sulphuric acid, or through the decomposition of a felspar there may arise carbonates of the alkalies, any of which, when in solution, are more energetic factors in promoting decompostion than water alone. Hence, under certain conditions, the process of decomposition once set in operation increases until such a depth is reached that the percolating solutions become neutralized and further action, aside from hydration, practically ceases.

Naturally soil moisture, with its content of soluble salts must tend to bring about chemical action in the nature of double decomposition. This is particularly true in regard to the action of such solutions upon the so-called zeolites. Zeolites are secondary minerals resulting from chemical changes taking place in pre-existing rocks, and indicate the first stages of rock decay; they are hydrous silicates of alumina, with varying percentages of lime, potash, and soda. These are the chief soil constituents to which the power of a soil to fix or retain bases from solutions is due.

The ordinarily feeble action of the air upon rocks is greatly increased by natural temperature variations. Rocks are complex mineral aggregates of low heat conducting power, each constituent of which has its own ratio of expansion or contraction. As the temperature rises each and every constituent expands and crowds against its neighbor; as the temperature falls a

corresponding contraction takes place. Slight as such movements may seem they are sufficient in time to produce a decided weakening effect, and serve as a starting point for other physical and chemical agencies. Such action is especially noticeable in regions where a cloudless sun heats the rocks so highly as to be uncomfortable to the touch and where at night the temperature sinks nearly to the freezing point.

The formation of humus from the remains of plant and animal life is largely dependent upon the chemical action of bacteria which in turn is controlled by climatic conditions. Thus in warm, not too moist climates, a mild, rich type of humus may be formed; while in cold, wet climates a sour, unfriendly type of humus results. The importance of humus in soil formation may be summed briefly as follows. It serves as a storehouse of nitrogen in the soil. It furnishes nutriment for bacteria and other forms of life. It produces carbon dioxide and other acids in its decay which increase the solvent action of soil moisture on soil constituents. It improves the physical condition of both light and heavy soils.

Ants by their numerous borings, penetrating at times to depths of many feet, bring about not only a rearrangement of soil particles, but also a condition of porosity whereby air and water gain access to the deeper lying portions, thereby promoting further chemical and physical changes. These creatures carry large quantities of organic matter into the soil and this, in addition to the excretions of the ants themselves, tends to further the processes of decomposition.

According to Darwin, the common earthworm produces widespread and beneficial results. These creatures burrow in moist, rich soil and derive their nutriment from the organic matter which it may contain. In order to obtain this comparatively small amount of nutritive material they devour the soil without any selective power and pass it through their alimentary tracts rejecting the non-nutritious portions which nearly equal in bulk that first taken in. While the main influence of the worms is seen in a mellowing by burrowing and in a transfer of materials from a lower to a higher level, they bring about a slight admixture of organic matter by dragging down small fragments of leaves and grasses, which, when taken into account with their excrement, must tend to enrich the soil to a greater or less extent. Darwin states that in certain parts of England these worms bring to the surface every year, in the form of excreta, more than ten tons per acre of fine dry mould. By collecting and weighing the excretions deposited on a small area during a given time he found that the rate of accumulation was an inch in every five years. The importance of worms both as mellowers of the soil and as levelers of inequalities is, therefore, not to be overlooked.

Thus we see that the soil is a very complex substance made up of more or less completely disintegrated rock fragments, with comparatively small amounts of organic matter derived chiefly from the decomposition of plant and animal remains, and supplied to a greater or less degree with moisture, and having a fauna and flora peculiar to itself.

By far the greatest portion of the soil is composed of inorganic or mineral matter, largely of a nature insoluble in water, hence not readily available.

This constitutes the so-called inert matter of the soil. The chief functions of this mass of inert matter are as follows: (1) To furnish standing room for crops, or a medium for their development of roots; (2) to serve as a reservoir for moisture; (3) to aid in regulating temperature by absorbing and radiating heat; (4) not the least in importance is the fact that this enormous mass of inert matter constitutes a storehouse of mineral constituents, including those which are necessary or essential for plant growth. These mineral constituents are mainly in a "locked up" or unavailable condition, and it is an important part of the agriculturalist's business to learn how to unlock and to render available these necessary ingredients for the use of crops. In other words, it is his business not only to maintain but to increase soil fertility. Some of the ways in which this may be done are by means of: (1) thorough tillage; (2) supplying humus or organic matter in the form of farmyard manure, in the form of green manuring, or by plowing in trash, stubble, and crop residues; (3) proper choice and application of fertilizers; (4) rotation of crops combined with fallowing when necessary.

It will be well to consider these points somewhat more fully. (1) The importance of thorough tillage can hardly be overestimated. Plants take their mineral constituents from the soil in the form of very dilute solutions, tillage promotes the formation of such solutions by exposing fresh surfaces to the solvent action of atmospheric and soil moisture. Tillage promotes the oxidation and aeration of the soil. It increases the activity of useful forms of bacteria, especially those which form ammonia and nitrates and those which fix the free nitrogen of the air. When properly conducted tillage has a beneficial effect upon the physical character of soils.

(2) The supplying of some form of organic matter which may be converted into soil humus by various soil agencies is of great importance also. Some investigators have emphasized this point particularly in connection with our Hawaiian soils. The benefits conferred upon a soil by humus are briefly as follows:—It furnishes a storehouse of nitrogen in organic combinations. This organic nitrogen is acted upon by useful bacteria and converted into ammonium compounds and nitrates which may be utilized by the crops. Humus furnishes nutriment for soil bacteria themselves and for other forms of life which in turn act upon various soil constituents unlocking them and rendering them available to plants. By its own proper decomposition humus produces carbon dioxide and other acids which increase the solvent action of the soil moisture, thus aiding in further disintegration of soils. It increases the retentiveness of light soils for moisture and improves the physical texture of both light and heavy soils. An abundant supply of humus tends to render a soil productive even though only small quantities of available mineral constituents are present.

(3) Agricultural chemists have proved that there are eleven chemical elements which are absolutely essential for normal plant growth. By an essential element is meant one in the entire absence of which a plant cannot develop properly. These eleven elements are carbon, hydrogen, oxygen, nitrogen, sulphur, phosphorus, chlorine, iron, calcium, magnesium, and potassium, which must be supplied in proper combinations. Of these eleven

elements but three, namely nitrogen, phosphorus, and potassium, need ordinarily give the agriculturalist any concern; these three are sometimes present in soils in such small quantity that their deficiency must be met by the addition of these elements in some available forms. They are usually added in the form of stable manure or as commercial fertilizers.

(4) Concerning rotations and fallowing it is not easy to make any definite statements as conditions differ so much in various places. It may be sufficient to call attention to the fact that under natural conditions, that is, when land is left to itself for a long series of years it often tends to increase in fertility. Part of this increase in fertility is due to the fact that amospheric nitrogen is fixed or combined by certain forms of soil bacteria and is then turned over to the soil; then, too, nature usually slips in various forms of legumes to help out what may be called a natural form of rotation.

There are certain constituents of soils which are concerned in maintaining soil fertility and which deserve more than a passing notice. These are the soil constituents to which the ability of a soil to fix or absorb bases is due. These constituents are known as zeolites. Chemically they are hydrated, double silicates of alumina and potash, or soda, or lime. They have power to absorb or fix, in rather loose combination, the bases ammonia, potash, and lime which may be applied as fertilizers, and thus to retain them in forms which are not easily leached out by water, but which can be appropriated by the roots of plants. Phosphoric acid when applied to a soil is usually fixed by certain basic constituents such as lime, ferric oxide, and alumina. Because of the high content of iron and aluminium oxides in our soils here, they have large absorptive or fixing power towards soluble phosphates.

In relation to crops, that constituent of the soil of immediate importance is the soil moisture since it is from this solution that plants through their roots draw all the material involved in their growth except the carbon dioxide and oxygen absorbed through their leaves. That is to say, the soil solution is the natural nutrient medium from which plants absorb the mineral constituents which have been shown to be absolutely essential to their continued existence and growth. Since this is the case it would be of the greatest value if the soil solution could be obtained from the soil exactly as it exists there. This is not possible of accomplishment as yet, though many efforts to approximate it have been made.

Some of the methods employed for this purpose are briefly as follows: (1) Extraction of masses of soil with water. One of the chief difficulties with this method is due to the fact that different extracts are obtained varying with the quantities of water employed. Such extracts are not true representations of the actual soil solution since they are the resultants of the solvent action of the soil moisture and the fixing or absorptive power of the soil. (2) By means of powerful centrifuges and saturated soil it has been possible to throw out the excess of solution over the critical water content of the soil. In this way small quantities of solutions, usually a very few cubic centimeters at a time, have been obtained. This is due to the fact that the soil solution, under conditions suitable for crop growth, is held by a force of great magnitude. (3) Displacement of the soil solution from soils in steel cylinders by forcing in oil under

high pressure has been tried. This appears to be a promising method and is under investigation by a number of soil scientists.

Quite recently the Bureau of Soils has been conducting some extensive investigations concerning the nature and functions of the soil solution and have published the results of one phase of the investigation in a recent number of the Journal of Engineering and Industrial Chemistry (Vol. 12, No. 7, p. 663), under the title, "Solid Phases Obtained by the Evaporation of Certain Soil Extracts." Briefly, the procedure consisted of taking from 400 to 2000 pounds of soil and treating it in portions of 25 to 50 pounds with from three to five parts of distilled water to one part of soil. After thorough agitation in a barrel-type churn the coarser material was allowed to subside for some hours and the liquid portion was then filtered through Pasteur-Chamberland filters. The clear solution was then evaporated in a steam-jacketed, tin-lined copper kettle until the specific gravity became notably higher, but before any crystalline salts except calcium carbonate and calcium sulphate were deposited on cooling. At this point the solution was poured into porcelain-lined dishes and evaporation was allowed to proceed at low temperature. As evaporation proceeded, crops of crystals were successively produced and separated from the liquid by filtering through paper filters. Usually from 10 to 15 crops of crystals were thus separated. The crystals were dried and the identifications were made by microscopical examination and petrographic methods.

The results indicate that the so-called plant foods are present in the complex mixture of single, double and triple salts entirely unlike the conventional combinations that chemists have heretofore assumed them to be.

It would appear from an examination of all the data that are available that the types of salts which have been found in the soil extract have a general resemblance to the deposits at Stassfurt and the inland sea and lake deposits which have been studied throughout the world. This is not at all surprising when we realize that the ultimate source of these deposits is the soil and that they have accumulated as a result of the evaporation of enormous quantities of river and sea waters that transported these soluble materials from soil sources. It would appear, therefore, that the soil is, in fact, a miniature Stassfurt deposit differing in detail with the character of the rocks and the processes of disintegration at certain points. Among the crystalline salts thus far identified as occurring in soils are such well-known minerals as sylvite, carnallite, and kainite.

This study throws a new light upon the soil solution, and is of much interest to the soil chemist. It opens up a large field of research as to the occurrence of particular types of salts and the possible significance of their presence on plant nutrition; also the possible change in the system by the addition of lime and fertilizer materials.

Certain forms of bacteria are so intimately associated with soil fertility that a brief discussion of soil bacteria should not be out of place.

Many changes take place in the nitrogen of the soil which are brought about by bacteria living in the soil. First of all there is the transformation of organic soil nitrogen into ammonia, which is known as ammonification. Next is the change of ammonia to nitrites, and of nitrites to nitrates, a change called nitrification. Under unfavorable conditions another change is possible; a change in-

volving the destruction of nitrates, either nitrites, ammonia, protein, or free nitrogen being formed. Such a change is known as denitrification. A further change is the production of organic nitrogenous compounds from the elementary nitrogen of the air; that is designated as nitrogen fixation.

Organic matter by decay is converted finally into carbon dioxide, water, ammonia or nitrates, and mineral salts. The general movement of organic soil nitrogen is towards the formation of nitrates, through ammonia, in spite of the presence of bacteria which act in the reverse direction.

Bacteria which affect soil nitrogen have been divided into seven groups, as follows:

(1) Bacteria which decompose organic nitrogenous substances and produce ammonia. This change is known as ammonification.

(2) Bacteria which oxidize ammonia to nitrites.

(3) Bacteria which oxidize nitrites to nitrates. These groups, 2 and 3, work together and produce the change known as nitrification.

(4) Bacteria which reduce nitrates to nitrites and ammonia.

(5) Bacteria which reduce nitrates to nitrites, and the nitrites to free nitrogen. These groups, 4 and 5, usually work together and produce the change known as denitrification.

(6) Bacteria which change ammonia, nitrites, or nitrates into protein or bacterial body substances. Bacteria of reduction.

(7) Bacteria which fix atmospheric nitrogen and cause it to form compounds. Bacteria of fixation.

A large number of different bacteria and moulds are capable of converting organic nitrogen into ammonia. Moulds probably do the larger part of the work in manure heaps and very peaty soils, but in ordinary cultivated soils bacteria predominate. The optimum or most favorable conditions for ammonification are a temperature of about 30 degrees Centigrade or 86 degrees Fahrenheit, complete aeration, and slightly alkaline reaction. The moisture and temperature conditions of the soil play an important part in determining the character of the bacterial flora and, therefore, the character of the chemical products formed. The mechanical and chemical constituents of the soil are also of decided influence.

Nitrification takes place in two stages or steps. First, nitrites are formed from ammonia; second, these nitrites are then changed to nitrates. Two kinds of bacteria are involved in this change, namely, the nitrous and the nitric organisms.

The optimum or most favorable conditions for rapid nitrification are: (1) A supply of suitable food such as potash, phosphoric acid, lime, sulphates, and carbon dioxide. (2) A suitable base or bases must be present, as the nitric acid must be neutralized as rapidly as produced, for the organisms will not thrive in an acid medium. Carbonate of lime is particularly useful for this purpose. On the other hand, too much or too strong a base is injurious. (3) Proper temperature must be maintained, as nitrification is most active at about 36 degrees Centigrade or 97 degrees Fahrenheit. It practically ceases at low temperatures. (4) Absence of strong light is important, as light tends to check the action of the organisms and finally destroys them. Hence a certain degree of shade is

necessary. (5) Freedom from salts in excess. It has been shown that large amounts of water-soluble salts are injurious to the activity of the nitrifying organisms. (6) An abundant supply of air or oxygen is necessary. A loose or porous condition of the soil is much more favorable than a compact condition. Thus a soil under cultivation allows more nitrification than a similar soil in pasture. As a rule conditions in Hawaii are favorable to nitrification.

The term denitrification is applied to the destruction of nitrates. Under certain conditions the nitrates in the soil are deoxidized with the production of organic bodies, nitrites, ammonia, or even free nitrogen. In this last case there is a loss of nitrogen from the soil. The conditions favorable for denitrification are as follows: (1) Insufficient supply of free oxygen. In water-logged soils or soils which are so compact that air cannot penetrate them, denitrification is very apt to occur. (2) The presence of a large amount of crude organic matter is objectionable. Cases are known in which a heavy application of fresh farm manure destroyed the nitrates in the soil and produced a smaller crop than if no manure had been applied. It is believed that a large increase in oxidizable organic matter favors denitrification, both by lessening the supply of free oxygen and by tending to rob the nitrates of their oxygen.

In conclusion I think we may see that instead of considering the soil as a mass of inert or dead material, we may look upon it as a complex mass of matter in the process of continual change and activity chemically, physically, and biologically.

In an article by C. A. Browne, entitled "Industrial and Agricultural Chemistry in British Guiana" (Jr. Ind. & Eng. Chem., 11, 874), he makes the following statement: "In its ultimate phase the study of soils is not simply an agricultural problem, as is sometimes imagined, but involves industrial and economic questions of greatest significance; for the soil, in whatever way we consider it, is that upon which not only manufactures and commerce, but all the phases of man's social life, depend. Probably no other kind of research requires the correlation of so many sciences; questions of geology, mineralogy, chemistry, physics, and meteorology are mutually involved, as well as those of biology and agriculture."

Report of Committee on Deterioration of Cane After Cutting.*

We give herewith a brief resumé of the report of Mr. Raymond Elliott, chairman of the Comimttee on Deterioration of Cane After Cutting. The report is filed at the Experiment Station and is available to anyone who may wish to study it in detail.

The report gives the results of twenty-three tests conducted on four plantations. Mr. Raymond Elliott reported the work from Paauhau Sugar Plantation Company, Mr. Henry L. White from Onomea Sugar Company, Mr. D. W. Richardson from Kilauea Sugar Company, and Mr. R. J. Richmond from Hawi Mill and Plantation Company.

* Presented at Eighteenth Annual Meeting of the Hawaiian Chemists' Association, held jointly with the Hawaiian Engineering Association, November, 1920.

The results of the individual tests are in some cases erratic and inconsistent. We believe this to be due to the methods of sampling. From work done here at the Station under very careful control we found that to get concordant results rather large samples must be used. Each bundle of cane should weigh at least 75 to 100 pounds and contain 40 or more sticks, which should be taken in consecutive order in the line; and rather than run samples every day, let it be every two days and interpolate between.

In summarizing the results, Mr. Elliott reports in part as follows:

The cane loses weight from the time it is cut until it is ground, although the conditions vary. When the weather is hot and with a breeze the loss in weight is at the maximum, whereas, when the atmosphere is saturated with moisture, the loss is lessened.

The difference between burned and unburned cane is distinctly seen at Paauhau and Kilauea.

The burned cane deteriorates faster than unburned cane, practically under the same conditions, with rainfall very slight in both places, for the first three days.

Taking the average after cutting for burned cane, the loss for the first day is 3.8%, representing five tests from three districts, variety Yellow Caledonia. For unburned cane, the loss for the first day is 2.52%, representing six tests from four districts, variety Yellow Caledonia.

For the second and third days the losses for burned cane are 8.88% and 9.67% as against unburned, which are 5.67% and 6.49% respectively.

The ratios in favor of not burning are: first day, 1.51; second day, 1.57; and the third day, 1.49.

Following are Tables 1 and 2, showing the averages for burned and unburned cane:

TABLE NO. 1.—BURNED CANE. VARIETY: YELLOW CALEDONIA.
% LOSS IN SUGAR.

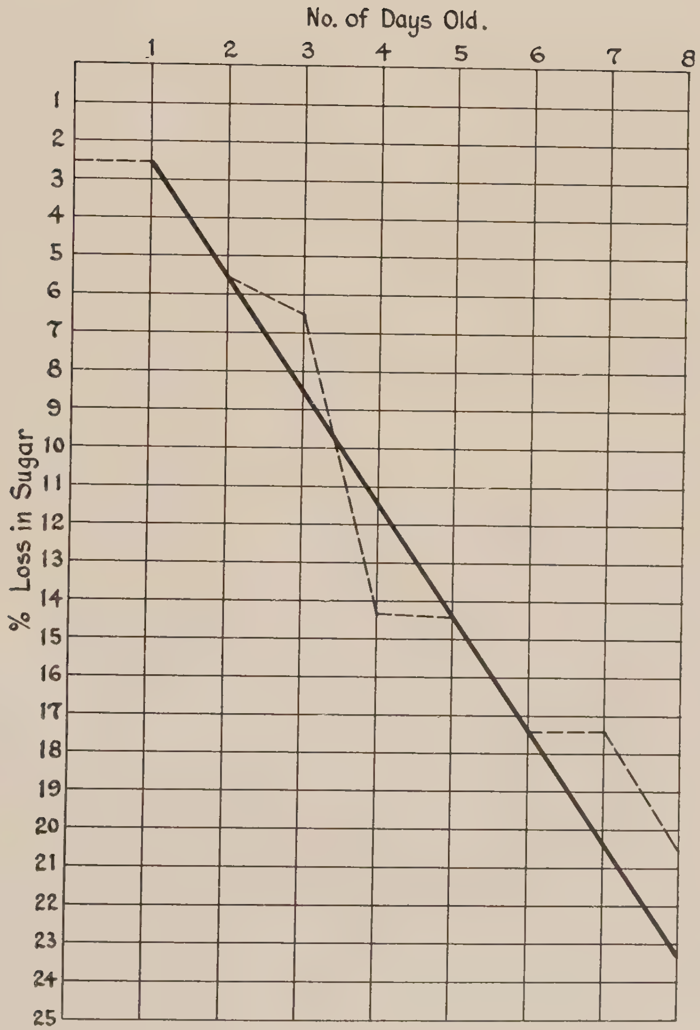
Plantation	Exp. No.	No. of Days After Cutting							
		1	2	3	4	5	6	7	8
Paauhau	1	.46	8.17	18.77	16.93	13.87	18.09	18.04	19.03
Kilauea	1	+2.30	.....	+1.8	2.6	9.6			
"	3	5.76	18.10	18.51	32.02				
"	4	8.49	8.93	7.96	7.29	12.62	.....	17.20	
Hawi	1	6.6	.3	4.9	3.3	+1.5	19.9	+3.0	28.6
Average—10	....	3.80	8.88	9.67	12.43	8.63	19.00	16.12	23.82

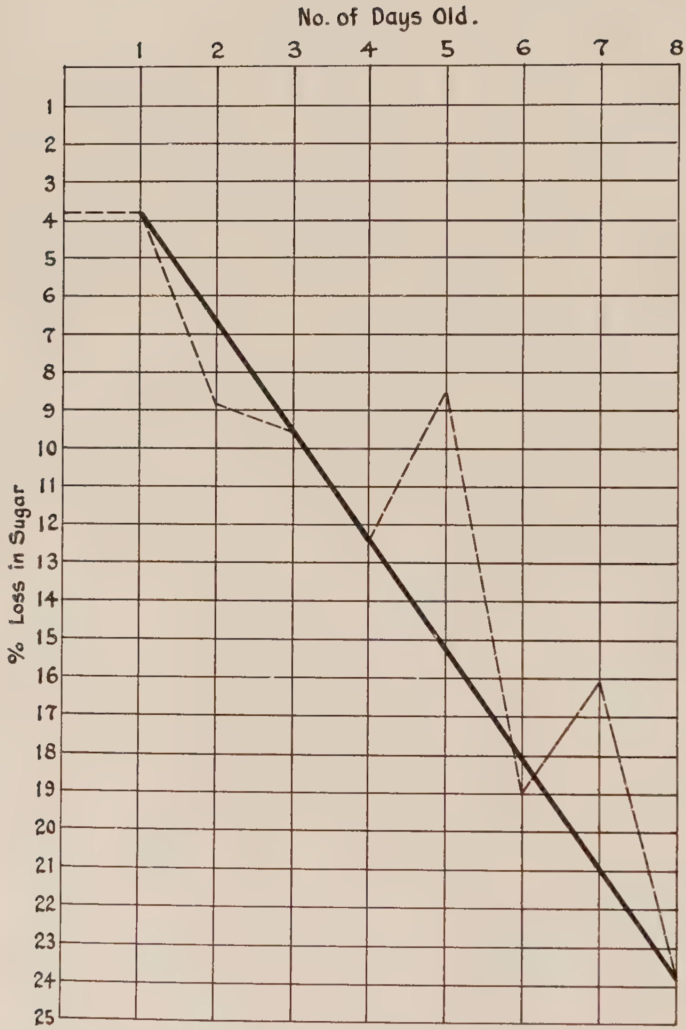
TABLE No. 2.—UNBURNED CANE. VARIETY: YELLOW CALEDONIA.
% LOSS IN SUGAR.

Plantation	Exp. No.	No. of Days After Cutting							
		1	2	3	4	5	6	7	8
Paauhau	3	2.22	3.70	5.25	12.58	19.18	21.27	28.05	30.02
Onomea	1	1.20	8.20	7.20	8.0	7.5	4.8	10.3	9.2
"	2	2.10	2.90	+ .5	8.8	3.1	3.8	1.5	3.2
"	3	+4.00	.9	2.4	4.4	8.1	8.9	12.8	16.8
Kilauea	2	5.00	4.8	5.7	.....	12.6			
Hawi	2	8.6	13.5	18.9	37.6	36.1	48.2	34.2	43.6
Average—13	....	2.52	5.67	6.49	14.28	14.43	17.39	17.37	20.56

N. B.—Onomea's cane assumed as unburned.

+ = plus values.


No. of Days Old.
1 2 3 4 5 6 7 8
% Loss in Sugar
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25



In the charts on pages 108 and 109 the per cent losses in sugar are shown graphically. The light lines show the average of the results of the different tests as actually obtained. The heavy line represents an attempt to smooth out the irregularities of the curves and represent what the true losses were from day to day.

J. A. V.

Adobe—Is Its Use Practical for Plantation Dwellings?

By Donald S. Bowman, *Industrial Service Bureau.*

The proper kind of earth for adobe construction is to be found on Oahu, Maui, Kauai, and sections of Hawaii. That adobe is a practical building material for climatic conditions similar to Honolulu is proven by the age and durability of buildings still occupied in Honolulu, such as the Damon House on Chaplain Lane, erected over eighty years ago and now used as headquarters for the Free Kindergarten Association. Adobe has been described as the building material of the ages, owing to the fact that as far back as we can go in building history we find from authentic records that the Hebrews, Syrians, Babylonians, and Egyptians had proved through long years of use its sterling worth. Adobe was formerly described as sun-dried clay, and the process of making the brick is today the same as that employed by the Egyptians—that of kneading with a binder of straw and baking in the sun. We find that it was used very extensively in Spain, and the building technique was taken to Mexico by the early Spanish settlers, where it became the chief building material, used by the rich and poor alike for the erection of homes and buildings. We find that the first adobe buildings occupied in the United States were those erected by the Pueblo Indians of Arizona. Later the early Mission Friars taught adobe brick making to the California Indians, and with their help erected the historic Missions standing today. During the reign of the Spanish and Mexican overlords in California, adobe brick made in the usual way, by hand, and sun dried, supplied the building material for their picturesque haciendas. This wonderfully cheap and adaptable material has stood the test of time. We know that not through the long ages has it been eclipsed in competition with kiln-dried brick or wood—this because of its manifest desirability, its ready adaptation into the changing architectural models of countries and periods, and, better yet, its absolute durability. Wood, which is inferior to brick or concrete, has been extensively used throughout the Islands more from habit and convenience, while adobe has not been considered owing largely to the fact that commercial firms have not been interested in its use. In California where the climate is similar to portions of the Islands, the use of adobe has been revived owing to two reasons: its easy adaptation into architects' and builders' plans is better understood than formerly; and still more important methods have been perfected for handling this material in combination with others whereby any possible objections have been eliminated. With modern methods of handling adobe construction and the scientific treatment by which it is adapted to the requirements of the twentieth century builder, we find it can be made to conform to today's wide range of structural conditions and to the demand for architectural designs of varied character. Owing to the shortage of building material in California and a growing demand on the part of some builders for the beautiful modified style of Spanish architecture, the use of adobe was welcomed as a practical necessity. That adobe construction has proven to be entirely satisfactory and practical may be seen throughout the southern part of California. At Walnut Park, where a large number of adobe houses are under construction, the builders have the following to say of their work:

"Our method of constructing these modernized adobe houses naturally is of interest to home-builders. Moreover, we are glad to give this information—based upon our actual experiences—in view of the increasing vogue of this material both for city and country dwellings.

"The initial stage of this process is the heavy concrete foundation which is put in place under all walls. This has a step for 2 x 4-inch underpinning, on the top sill of which rest the wooden floor joists. Inside, the joists are carried on beams supported by concrete piers and posts, in the usual manner of house construction. The joists are then covered with the rough sub-flooring and the interior stud partitions set up on same. The ceiling joist and rafters are then put in place and carried at the wall line by temporary struts. When built into the wall they rest on a 2 x 6-inch redwood plate mopped with asphaltum.

"The window and door frames are then set up in their proper places at the right height and, where the adobe walls are to be constructed, they are blocked up and braced in place. At each corner and angle of the house, a batter board is erected, plumbed true, and lines marked horizontally at 12-inch intervals for the guidance of the bricklayers. The top of the concrete foundation is then thoroughly mopped with a heavy coat of asphaltum waterproofing, and the job is ready for the mason work.

"The brick is laid to lines stretched from the batter boards, by common labor, under the supervision of a competent foreman. It is laid up in a clay mixture of the same consistency as the brick. Concrete lintels are cast either in place or on the ground for the openings, and a 4-inch concrete coping is cast on the parapet, where the flat roof form of construction is used. The composition roofing is carried up the parapet under this and the waterproof plastering is carried back over the joint, making a tight waterproof job. The house is then ready for the exterior plastering.

"Nails are driven into the adobe brick so that the heads project about three-eighths of an inch. A thin dash coat of cement plaster is then sprayed on the wall. This forms a key for the rough or brown coat, which is not less than 1 inch thick in any spot. The finish coat of silica sand and white hydrated cement is then put on with the character of finish specified and the whole waterproofed with a coat of transparent, standard waterproofing compound. The matter of interior wood trim is optional.

"Our adobe houses thus constructed have been found to possess advantages not obtained with any other form of construction in this climate, which is subject to a rather wide range of temperatures. The clay walls are a perfect insulation against heat and cold. No trouble arises from sweating walls. Homes of 'Modernized Adobe' are as permanent and enduring as those of brick or tile, and they cost less than half as much. Moreover, these houses are dry and warm in winter and cool and comfortable in summer when the heat rays are severe. When properly ventilated, the air in them is always sweet and clean. The heavy walls impress one with a beauty, dignity, and strength not obtainable except at great expense in any other form of construction. The interiors can always be made cosy and restful, and for comfort and health it is doubtful whether a more perfect type of home has been devised."

The adobe buildings erected throughout the southwest in the early days had no exterior finish, but were in many cases plastered within. In order to present first-hand information we wrote to a former Island man now residing in California for information in present-day adobe construction, and this is what he writes:

"Mr. John Byers, 547 Seventh Street, Santa Monica, California, is the man who is doing the biggest business in this line. I was looking for him for about a month and finally located him in Beverly Hills, the city where Burbank and his

wife reside, where he is constructing a fine Spanish style of a building of this adobe. I just jotted down a few things he gave me: Adobe bricks are 4″x 14″x 20″, and he finds with labor at about $5.00 a day that he can make them for $50.00 per one thousand, and would make that price for market. The earth about here is of the adobe kind, and all he does is to dig down where the cellar is to be and mold his brick with the straw right on the ground and let them sun bake, so that by the time he has put in the concrete foundation of from four to twelve inches from the ground and of sufficient width to bear the weight of the brick, his brick will be ready to pile. Pile is about the word, for he just seems to pile them up and the only caution seems to be to keep the house level by keeping the tiers of adobe level. He said the labor to lay 1000 of these bricks was about $100.00 if you counted the labor at $5.00 per day.

"An ordinary six or seven-room house takes 5000 bricks, so you see the expense of the construction is less than half of the price of a carpenter-made house, and the material has proven that it is less than half a tile house and one-quarter the price of lumber.

"The plastering is done quickly and the proof of the keeping properties of the house is in the old missions that have stood for hundreds of years, and many are still standing.

"Byers expects that the houses he has built will be in their places a thousand years from now unless some unusual disturbance comes to carry them away.

"These houses are warm in winter and easily heated, and are cool and dry in the summer time.

"I surely am pleased with the prospects of the thing, and now I want to get samples of the soils down there. Mr. Byers says his experts will tell us in a few minutes as to the possibility of using them in construction down there. Rain will not affect it if the coating of cement on the outside protects it, and the concrete bases keep it from the dampness of the ground and the surface water. If you will send me some samples of the soil from the several places you have thought of for building, I will take them to the expert and have his opinion upon it, and the possibilities are of a new industry in Hawaii."

From the information at hand and the success attained in adobe construction throughout the southwestern sections of the mainland, it is apparent that it would pay the plantations favorably located as to adobe soil and climatic conditions similar to Honolulu, to investigate and experiment with adobe.

Feeding Plantation Animals.*

By W. A. Wendt.†

Although at first thought it may seem that feeding is a simple proposition, if carried on properly it is a problem which requires careful consideration.

In all feeding work we must take into consideration the following points:

1. The type of animal with reference to its digestive system.
2. The purpose for which the animal is kept, e. g., meat, milk, work.
3. The feeds which are available.
4. The problem of arranging some system of feeding which will yield the most economical returns.

* A lecture presented at the University of Hawaii, Short Course for Plantation Men, October, 1920.

† University of Hawaii.

In ruminants, ox, sheep, and goat, we find the four stomachs. The food is masticated but slightly before it passes into the first stomach. Here the mass of food lies and is partly broken down through bacterial action. It is later forced back into the mouth and remasticated, or, as we say, the animal "chews its cud." The food is then reswallowed and passes into the other stomachs to be acted upon by the digestive juices.

The bacterial action in the first stomach, together with the remastication, makes it possible for this type of animal to make use of larger quantities of coarse roughage with greater efficiency than the horse or hog, because the resistant fiber and cellulose is partially broken down into a form available as food.

The horse and hog, having only one stomach, cannot handle large quantities of roughage as efficiently as animals which chew the cud. They must therefore receive feeds adapted to their type of digestive tract.

Any substance in a feed which aids in the support of life is known as a *nutrient*. The common classes of nutrients are proteins, carbohydrates, and fats. Not all the nutrients in a feed are in an available form, hence we get the term *digestible nutrients* as applied to the portions of the nutrients which are digested and taken into the body. A ration is the amount of feed allowed an animal for one day. In order to get the most economical use out of a given ration, it is necessary that this ration be balanced, i. e., the several nutrients, protein, carbohydrates, and fat be furnished in the proper proportion.

The proportions of nutrients necessary depends on the purpose for which the animal is fed; that is, for the production of meat, milk, or work. Any animal requires a certain amount of food to maintain its body, to repair broken, wornout tissue. If we wish this animal to increase in weight, furnish milk, or do a certain amount of work, we must furnish feed which will supply nutrients enough to enable the animal to do this extra work in addition to maintaining its body.

We find that a growing animal increases rapidly in body weight in protein and mineral matter. These nutrients, therefore, must be furnished liberally in the ration of an animal maintained for meat production. Fat is also stored up in the body of a meat-producing animal and is formed largely from the carbohydrates in the food. A mature fattening animal requires very little protein, but a large amount of carbohydrates. Milk is rich in protein and minerals which must be furnished in the ration of the milk-producing animal.

The following are rules which are helpful in determining the proportions of concentrates and roughages required by various classes of animals:

1. Mature, idle horses or mature cattle can be maintained at a constant weight on a good grade of roughage alone—common hay and grass.

2. Horses at work require 1.5 lbs. concentrates (grains) and 1.5 lbs. dry roughage daily per 100 lbs. live weight.

3. Dairy cows in milk require daily 2 lbs. dry roughage per 100 lbs. live weight and 1 lb. concentrates per 3-4 lbs. milk produced.

4. Fattening steers require 1 lb. dry roughage and 1.5 lbs. concentrates daily per 100 lbs. live weight.

5. Pigs require mostly concentrates, being able to make but little use of roughage.

Horses and mules are maintained for work and must be fed a ration which supplies the necessary energy-producing nutrients. Experiment has shown that the carbohydrates and fats of the food are first drawn on as sources of muscular work.

The source of the carbohydrates will be the concentrates in the ration. On plantations, perhaps, the most economical carbonaceous concentrate is molasses. This may be poured on the roughage or mixed with the grain. Some grain, oats, barley, or bean meal should make up part of the concentrate ration. Although oats is the ideal grain for horses, a long series of tests has shown that barley is equal to oats as a feed.

The roughage may consist chiefly of cane tops, although if clover or alfalfa hay is fed, not over 1.2 lbs. per 100 lbs. live weight, the amount of grain supplied may be cut down considerably. A definite allowance of roughage should be fed to prevent the horse overeating and becoming subject to digestive disorders. Mules will not overeat. The larger portion of the ration should be fed at night, thus allowing plenty of time for mastication and digestion. Feed one-fourth in the morning, one-fourth at noon, and the remainder at night.

The following table would be very useful in balancing the ration for plantation animals:

AVERAGE DIGESTIBLE NUTRIENTS IN FEEDING STUFFS.

Name of Feed	Total dry matter in 100 lbs.	DIGESTIBLE NUTRIENTS		
		Crude Protein	Carbo-hydrates	Fat
Sugar Plantation Products	lbs.	lbs.	lbs.	lbs.
Cane top hay (estimated).....	63.2	2.0	38.0	1.2
Cane tops, green (estimated)..	15.8	0.5	9.5	0.3
Molasses.....................	74.1	1.4	59.2	0.0
Hawaiian Grown Feeds				
Dried roughages—				
Peanut vine hay	92.4	6.7	42.2	3.0
Para grass (dry)	...	5.5	45.6	0.6
Alfalfa hay	91.9	10.5	40.5	0.9
Green roughages—				
Alfalfa	28.2	3.6	12.1	0.4
Cowpea vines	16.4	1.8	8.7	0.2
Bermuda grass	28.3	1.3	13.4	0.4
Root crops—				
Cassava	34.0	0.8	28.9	0.2
Sweet potato	28.9	0.8	22.9	0.3
Concentrates—				
Rice Bran	90.3	7.6	38.8	7.3
Corn	89.4	7.8	66.8	4.3
Algaroba meal (total nutri).	...	9.8	55.2	1.2
Imported Feedstuffs				
Barley	89.2	8.4	65.3	1.6
Wheat bran	88.0	11.9	43.1	3.1
Oats	89.6	8.8	49.2	4.3
Cottonseed meal	93.0	37.6	21.4	9.6
Cocoa meal	89.7	15.4	41.2	10.7
Tankage	93.0	50.1	0.0	11.6

FOOD REQUIREMENTS OF DIFFERENT ANIMALS PER DAY PER 1000 LBS. WEIGHT.

	Dry matter	Crude Protein	Carbo-hydrates	Fat	Nutritive ratio
Horses and Mules	lbs.	lbs.	lbs.	lbs.	
Light work......	20.0	1.5	9.5	0.4	1—7.0
Medium work...	24.0	2.0	11.0	0.6	1—6.2
Heavy work.....	26.0	2.5	13.3	0.8	1—6.0
Fattening Cattle					
First period.....	30.0	2.5	15.0	0.5	1—6.5
Second period...	30.0	3.0	14.5	0.7	1—5.4
Third period....	26.0	2.7	15.5	0.7	1—6.2
Milk Cow					
11.0 milk daily...	25.0	1.6	10.0	0.3	1—6.7
22.0 " " ..	29.0	2.5	13.0	0.5	1—5.7
27.5 " " ..	32.0	3.3	13.0	0.8	1—4.5
Brood Sow........	22.0	2.5	15.5	0.4	1—6.6
Fattening Swine					
First period.....	36.0	4.5	25.0	0.7	1—5.9
Second period...	32.0	4.0	24.0	0.5	1—6.3
Third period.....	25.0	2.7	18.0	0.4	1—7.0

PLANTATION STOCK FOODS PREPARED BY THE HAWAIIAN COMMERCIAL AND SUGAR COMPANY.

SUGAR BRAN—"MULES DELIGHT"

Dried brewer's grains 10.5%
Algaroba bean meal 35.0%
Alfalfa meal 13.2%
Dried cane bagasse 6.3%
Cane molasses 35.0%

CONTAINS

Dry matters 86.7%
Digestible protein 7.5%
Nutritive ratio 1—6.9
Home grown constituents.......... 89.5%
H. C. & S. Co. cost—$20 per ton.*

SUGAR BRAN—"DAIRY FEED"

Coccanut meal 6.8%
Dried brewer's grains 6.8%
Algaroba bean meal 33.8%
Alfalfa meal 12.7%
Dried cane bagasse 6.1%
Cane molasses 33.8%

CONTAINS

Dry matter 86.8%
Digestible protein 7.8%
Nutritive ratio 1—6.7
Home grown constituents........... 86.4%
H. C. & S. Co. cost—$21 per ton.*

SUGAR BRAN—"HOG FEED"

Blood meal 3.8%
Cocoanut meal 3.8%
Algaroba meal 37.5%
Alfalfa meal 14.0%
Dried cane bagasse 3.4%
Cane molasses 37.5%

CONTAINS

Dry matter 86.2%
Digestible protein 9.0%
Nutritive ratio—1-5.9.
Home grown constituents 92.4%
H. C. & S. Co. cost—$21.25 per ton.*

(Tables and data given above secured from "Feeds and Feeding" by Henry, and from the Hawaiian Planters' Record.)

* Old prices.

Testing Welds.*

By S. W. Miller, M. E.

The question of testing welds is one that has been considered more or less since welding was known, but especially during the last five years. Its importance has now become very great. There have been many failures in the past, many of them not having been explained and some of them having been very expensive. As in all other developments, welding first received its principal impetus from the practical man. Of late, however, the tendency has been to investigate more carefully and more fully and by means not available to the ordinary welder. This means that scientists of all kinds have been called into consultation and that almost every conceivable method of test has been suggested in order to determine what methods and materials would make the best welds from a standpoint of security, service and cost.

The welding of steel is frequently considered as not being especially difficult, and it is also sometimes considered that steel is steel and that no different treatment is required in the case of different qualities and varieties of steel. This idea is much less common today than it was several years ago, but it is still too prevalent for the good of the art. It is not well known as it should be that a comparatively small difference in the percentage of carbon in the material being welded makes a very great difference in the results of either a bend or tensile test. If the carbon is 0.12 per cent or less, the material is soft, ductile and yields readily to any strain that may be put on it. Such material is frequently used for tanks and, because of its ductility and comparative freedom from damage by heating, is admirably suited for welding. Structural steel, bar steel and boiler plate contain about 0.15 per cent to 0.25 per cent carbon and have a tensile strength of about 60,000 lb., while the soft low-carbon material has only about 52,000 to 55,000. Ship plate is required to have a tensile strength of from 58,000 to 68,000 lb. and in the heavier sections requires as high as 0.30 per cent carbon. It has been found by experience that the higher the carbon, the more difficult it is to get a satisfactory weld and the more danger there is of injuring the metal being welded. It is also evident that a weld made with a given welding rod or electrode can have only a given strength. If this strength is greater than that of the material being welded, the test piece will always break outside of the weld. If, on the other hand, the weld is weaker than the material being welded, the rupture will always take place in the weld. An oxyacetylene weld made with ordinary low-carbon welding wire will have a tensile strength of about 52,000 lb. This is stronger than soft tank steel and weaker than the other materials mentioned. It is possible to get with alloy steel rods of proper composition a tensile strength in an oxyacetylene weld of about 50,000 lb. Neither of these materials will weld boiler steel, boiler plate or ship plate, so

* Abstract from a paper read before the September meeting of the Chicago Section of the American Welding Society.

that the rupture will occur outside the weld when the section of the weld is the same as the section of the piece, and in making tests of welded pieces, it is necessary to know accurately the character of the material being welded.

The method of test to be applied in any given case depends largely on the use to which the welded piece is to be put. If it is to be used in a pressure vessel, I believe that not only should a tensile test be made, but that an alternating stress test should be used because of the breathing of the tank due to changes of pressure. This latter test should also be applied where the weld is subjected to bending strain. There are no standards at present for weld tests, but it is advisable, wherever possible, to follow those of the A. S. T. M.

The best test, in my opinion, to determine quickly the general character of a weld, is to grind it off level with the surface of the pieces and clamp it on an anvil, with the center of the weld level with the top of the anvil, the bottom of the "V" toward the anvil so that the top of the weld is stretched when the projecting end is struck with a sledge. The blow should not be too heavy, and the number of blows and angle to which the piece bends before cracking are quite a good index of the value of the weld. It is true in this test, as in the tensile tests, that the quality of the material being welded has a great influence on the results. Stiff material throws more of the strain into the weld, while soft ductile material will itself take considerable of the bend. In the case of defective welds—that is, those not fused along the "V" or which contain slag or other inclusions—this test will at once develop the defects. If a welded piece were to be used in a place where it might became red hot such as, for instance, in a locomotive firebox crown sheet, it would be entirely proper to test the welds at a good red heat by clamping them in a heavy vise or on an anvil with the center of the weld about half an inch from the edge of the vise or above the face of the anvil, heating them to a bright orange with the torch and then bending them as before as with a sledge.

If such welds are made in a ½ x 2-inch bar steel, a 90-degree single "V" being used, and they bend to a right angle cold without cracking on the outside, a welder may feel well satisfied with his work.

Testing Rails for Hidden Defects.

There has recently been developed a method for testing rails for hidden defects which was devised by A. M. Waring. It consists of deeply etching a polished surface of the material under test. For instance, a section of a weld might be cut out with a hacksaw, machined or filed to a true surface, and polished on various grades of emery paper, ending up with 00 Manning. It is then placed in a warm solution of 25 per cent hydrochloric acid and water for from one-half to an hour. The acid will eat away the defects, making the edges of the material at them taper, so that rather large grooves and pits will be visible where the defects prior to the etching would be only microscopic. The etching test I consider to be of the greatest value in ordinary shop practice where it is desired to find out rapidly and quite accurately the quality of the work done by the different welders.

These rough tests, while satisfactory for determining the general quality of the work, do not answer as a basis for design, and more refined tests must be used

as before referred to. I believe that the most important of these are the tensile and alternating-stress tests. The tensile test can be made in any shop provided with the usual tensile testing machine. The alternating-stress test is not as yet standardized even for unwelded material. I am inclined to believe that the machine devised by the Quasi-Arc Company is of considerable value, although it does not give absolute results; that is, it does not give the amount of fiber stress to which the piece is subjected.

A great deal may be learned from the appearance of a weld. It is difficult to describe the appearance of good welds, but after they have been seen a number of times, an inspector can readily say whether the operator knows what he is doing. In gas welding, I would not accept a ripple weld in heavy material nor one which was narrower than about 2½ times the thickness of the sheet, because I have never seen a weld having these appearances that was properly made. The appearance in a gas weld of porosities on top indicates that the metal has been overheated, and the same thing is true in an electric weld. Inasmuch as I believe that the serious defects in welds are caused by oxides, it would appear wise in the case of gas welding to use no larger top than is necessary to produce thorough fusion. This means that the catalogue speeds of welding are impossible if good welds are desired. The same thing is true of electric welds. The reason is that at the high temperatures of the steel caused by too large a tip or too heavy a current, the metal becomes overheated, and in that condition combines more readily with the oxygen of the air or with any excess oxygen in the torch flame, and produces oxides which are readily dissolved by the melted metal. As the metal cools down, these oxides are rejected in large part and pass to the grain boundaries, as do other impurities, so that it is perfectly natural that material that has been seriously overheated should be more brittle and weaker than the material that has been properly melted. In conclusion, I have found in a number of cases that very great improvements in the quality of the work were made by using regularly the bending test already described and by carefully instructing the welders until they were able to make welds that would meet this test with unfailing regularity.

A New Method of Rat Repression.*

Applying a Sex Law.

Mr. George Jennison, of Belle Vue, reading a paper before the Conference of Rat Officers at the Royal Sanitary Congress at Birmingham yesterday, said that noxious rats appeared in France about 1755 in the neighborhood of the great menageries of Versailles, Chantilly, and Marly la Ville, and had probably been imported as curiosities from India. According to Buffon, they multiplied prodigiously and did great damage. That their ravages were as great in England is proved by the vogue of Robert Smith's "Complete Rat-Catcher," a three-

* From an English paper.

page pamphlet that sold for a guinea. His method still held—destruction by dogs and infallible baits,—but, in spite of continual persecution both from necessity and as a cheap and popular sport, the rat held its own or increased everywhere, from two reasons. First, living near man protected it from all natural enemies; secondly, its great fecundity mocked all efforts for its annihilation.

"Boulter," he said, "estimated the rats as equal to the human population and their annual cost at £15,000,000 (it would now be £40,000,000). He stated the potential increase of one female in a year as 880, but that was grossly below the mark, as he took his average litter as four males and four females, whereas the proportion is four to six, and the potentiality therefore about 1350. Taking only one-sixth of this figure, the females alone would increase 130-fold annually, which means that ten females might leave 170,000 females, besides 120,000 males, in two years." So there were evidently other checks. Food scarcity was the chief; rationing had resulted in great catches of females. The other great check was struggles amongst the rats themselves, and particularly the harrying of the breeding females. It was precisely on these two points that men helped the rat to survive—the more killed, the more food for the remainder, and as the males are bolder than the females and are caught therefore in disproportionate numbers, not only was breeding made easier, but the rat became more polygamous and the evil was thereby increased.

Mr. Jennison advocated catching the rats alive; killing the females and releasing the males. The idea, he said, was given to him by Mr. Isaac Bailey, formerly gamekeeper at Swythamley Hall, Macclesfield. Later he found it had been used by Mr. William Rodier, of 327 Collins street, Melbourne, who claimed to have cleared 64,000 acres of a rabbit-infested district in 20 years by this means alone, whereas poisoning, which is obligatory in Australia, had been and is a failure. The lecturer said that on this evidence he had changed his own destructive methods for the new system with marked results, and submitted the following table of results at Belle Vue:

	Trappings	Males	Females	Total	Average per Month
1915—Oct. 11-Dec. 31.	8	40	45	85	34.6
1916—January-June.	12	96	82	178	30
July-December	11	50	92	142	24
1917—January-June.	14	60	84	144	24
July-December	12	72	135	207	* 34.5
1918—January-June.	12	35	104	139	23
July-December	12	41	64	105	17.5
1919—January-June.	13	40	68	108	18
July-December	13	55	50	105	17.5
1920—January-June.	13	52	59	111	18.5

* Caused by rationing and food scarcity.

Under his system the reduction was gradual and the results little affected by food, which had been quite normal since the Armistice, and males were now being caught in larger proportions, which showed that the balance of sexes was being disturbed in the right direction.

Summarized, the matter stood thus:—Rats are to be exterminated; they do, say, 30 millions of damage annually; they cannot all be killed—killing many has little value; easier feeding means quicker breeding; a small neglect means a swarm renewed; the disposal of dead rats is a serious sanitary problem; the Rodier method—killing females only—is slower and more difficult, but it is efficacious in plenty or scarcity—it allows for long periods of neglect, it works in Nature's way; you can only conquer Nature by obeying her.

Mr. Jennison asked the conference not to reject the idea because it was new and strange—there was really nothing novel about it; every one of them who bred horses, dogs, sheep, poultry, pheasants or pigeons knew that an excess of males meant failure, and regulated the supply accordingly. They were unwittingly doing the same with rats and getting the same results, whereas they wanted the contrary to happen. He also drew attention to two cases where the sex law had been unwittingly applied to wild creatures. First, the male bird of paradise, never very numerous as a species, had been hunted for plumes for two thousand years: result, the race became polygamous and still survives. Secondly, the passenger pigeon, counted by the thousands of millions only a century ago, was hunted at nesting-time, when the female sits for 20 hours in the day, consequently they were killed in excessive numbers: result, the race was exterminated in 60 years.

The lecturer also submitted a table of the captures in Copenhagen, where there was a very efficient rat law. He noted that in the first year under this law an enormous proportion of rats was killed—the figures were 312,949,—but that for seven years afterwards all the Danish effort produced no effect whatever; the subsequent reduction was due to the war and food scarcity. As food supplies increased and buildings were likely to deteriorate the captures in that city would, he predicted, reach 150,000 shortly.

[J. N. S. W.]

Air-Pump Capacities and Incondensible Gas Volumes in Industrial Vacuum-Evaporator Plant.*

By Edward Corner.

The rather unfortunate general use of empirical formulæ for the determination of air-pump capacities in evaporator work has led the writer to attempt to lay down in a clear and concise manner the theoretical principles entailed, with practical data and a set of curves, which will enable designers to choose the correct value for any particular case.

Empirical formulæ are undoubtedly most useful in average cases, and under satisfactory conditions designs obtained by their use are good enough for practical purposes, but many cases have occurred in which a fuller knowledge of the root principles would have been of extreme value to the designer, and would undoubtedly have enabled him to produce a more efficient and satisfactory apparatus. It is often remarked by draughtsmen and engineers, who have been con-

* Reproduced from Engineering, 1920, CIX., No. 2820.

nected with more than one firm, how great the variation is between the empirical figure taken in one shop and that taken in another, and the writer is personally acquainted with three different values for the capacity of dry-air pumps, values which differ so greatly that it is difficult to explain the fact that these firms are all makers of very satisfactory plants.

Now, empirical formulæ, especially as regards condensation problems, can only be considered accurate or practically accurate between certain limits, i. e., a single value for, say, air-pump capacity cannot be expected to cover all variations of injection temperature, vacuum, or hot-well temperature, and it is essential that in many cases an accurate factor should be obtained, applicable to the particular conditions prevailing.

The possible vacuum in any condenser is directly due to the absolute pressure in the condenser, this absolute pressure being the sum of the partial pressure of water-vapor and air or other incondensible gases present.

According to Dalton's Law, any number of gases enclosed in a vessel will each exert a pressure upon the walls of the vessel equal to the pressure such gas would have exerted had it been present alone, and the total pressure in the vessel is the sum of the partial pressures of all the gases present. Also, each gas occupies the whole space, or, in other words, the molecules of the different gases are intimately mixed.

The temperature prevailing in a condenser is, approximately, that of the outgoing or "tail" water, and it is easily seen that this temperature is the governing factor in fixing the vacuum. It is sometimes thought that the quantity of air relative to steam, entering the condenser, plays an important part in determining the vacuum, but as the ratio of air to steam is always very small, the actual effect can safely be neglected and, in fact, has no influence whatever in the latter part of the condensation, i. e., after the latest heat has been removed. Immediately after condensation of the steam, the ratio of air to vapor becomes very greatly increased, and the partial pressure of the air becomes a very important factor in determining the vacuum, and it is this partial pressure of the air which explains the difference between the vacuum shown on the gauge and the vacuum which one would expect from the relative thermometer reading.

The volume of 1 lb. of air enclosed in a space, at any temperature and pressure, is found as follows:

$$V_2 = \frac{V_1 P_1 (T_2 + 460)}{P_2 (T_1 + 460)}$$

where V_1 = volume of air in cubic ft. per lb., at 60° F., and 14.7 lbs. per sq. in. = 13.1 cu. ft.
V_2 = volume as above, at P_2 and T_2.
P_1 = 14.7 lbs. per sq. in.
P_2 = Pressure of air at T_2 and volume required.
T_2 = 60° F.

Substituting the given values in the above formula, we get:—

$$V_2 = \frac{13.1 \times 14.7 \times (T_2 + 460)}{P_2 \times 520} = \frac{0.37 (T_2 + 460)}{P_2}$$

In a mixture of steam and air, at any given volume and temperature, the volume of the air is equal to the volume of the steam, and also equal to the total volume, and its weight is:—

$$W = \frac{p_2 \times V}{0.37 \times (T_2 + 460)}$$

where W = weight in lbs. of the air contained in the mixed volume.
P_2 = pressure of the air, which is equal to the total pressure minus the pressure of the water vapor or steam at temperature T_2.

Fig.1. WET-AIR PUMPS JET CONDENSERS.

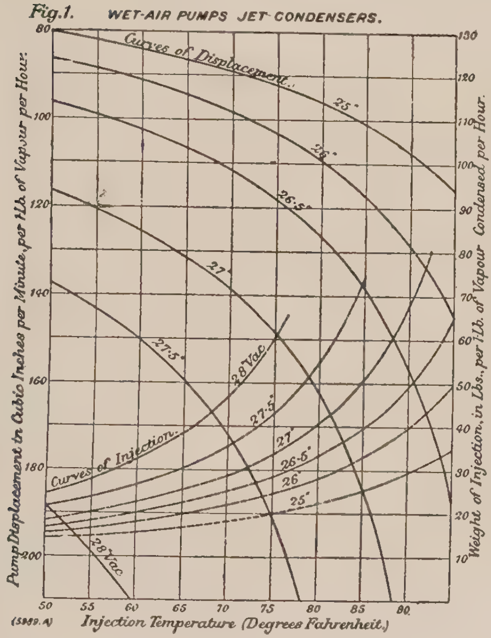
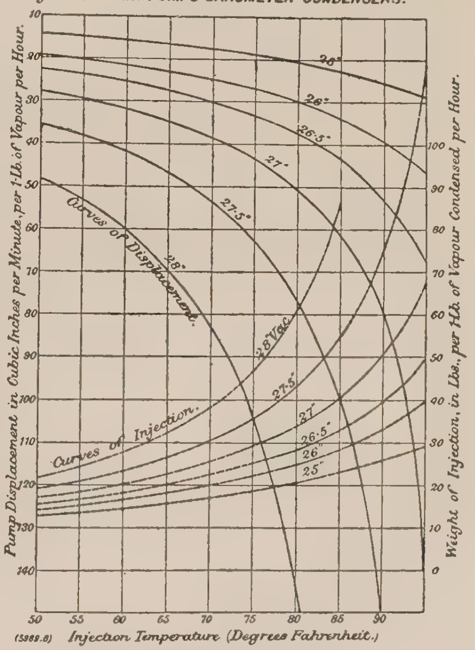


Fig.2. DRY AIR PUMPS BAROMETER CONDENSERS.



The usual allowances or data for ratio of air to steam, which are applicable to power plants, are very much too low for industrial evaporator work, as this latter plant exposes a much greater joint surface, and is working with liquors which contain a large quantity of gases in solution, as well as other gases which are evolved during the evaporation process. On the other hand, the water used for injection is very often at a much higher temperature than that used in European plant, and thus contains slightly less air; this, of course, is only intended to apply to tropical conditions, and chemical evaporators working in Europe would, naturally, have conditions of injections similar to power-plant in the same locality.

The most reliable figures for incondensible gas volume relative to steam entering the condenser are as follows:

(1) 4 lb. of air per 1000 lbs. of steam or vapor.
(2) 0.2 lb. of air per 1000 lbs. of liquor treated.
(3) 0.1 lb. of air per 1000 lbs. of injection water.

These values are originally intended for sugar-juice evaporators, but can be used with confidence for almost all chemical liquors, and for any temperature of

injection. The quantity, under heading (2) above, varies with the number of vessels in the evaporator, and a table of constants is given for the various groupings, as the curves are all calculated for the most usual triple-effect grouping; a set of multipliers is also appended, to facilitate calculation.

As previously mentioned, the possible vacuum in any condenser is directly due to the temperature of the "tail" water, and in condensers of the jet type this tail water is the condensed steam, together with the injection water. The formulæ for obtaining air-pump capacity for any type of jet condenser are very similar, only differing in respect of the values taken for the temperature at which the air is withdrawn, and in the case of barometric or counter-current jet condensers, the pump is not required to deal with any tail water, and thus no factor for this is embodied.

Now, as stated above, the most important factor in determining the possible vacuum is the temperature of the tail water, and indirectly this temperature greatly affects the volume of air which must be withdrawn. Every pound of injection water brings with it a certain quantity of air, and thus the greater the quantity of injection water used the greater the quantity of air which must be removed. Against this must be placed the fact that, the greater the quantity of injection water used, the lower will be the temperature of the tail water, and consequently a higher vacuum will be obtained, together with a lower air temperature and smaller volume per pound. A set of curves plotted for this purpose shows a marked diminution of air-pump volume, with increase of injection water ratio up to a certain limit, after which pump capacity rises rapidly, on still further increasing this ratio.

To find the ratio $\frac{\text{injection water}}{\text{steam}}$ by weight, the following simple formula is used:

$$W = \frac{L + (T_1 - T_2)}{T_2 - T_3}$$

where W = weight of injection water per pound of steam per hour.
L = Latent heat of the steam at temperature due to required vacuum. or T_1.
T_1 = Temperature of steam at the required vacuum.
T_2 = Temperature of the "tail" water.
T_3 = Temperature of the injection.

It is usual to assume T_3, 10° below T_1 for low-level, parallel-flow jet condensers, and 5° below T_1 for barometric or other counter-current jet condensers. These allowances are considered sufficient in most cases, but the designer must satisfy himself, in special cases, that the temperature difference given by these values is sufficient for the complete transmission of the heat during the passage of the steam through the condenser, or, in other words, that the condenser is of sufficient length. The curves in Figs. 1 and 2 are plotted for conditions as given above; other conditions will, of course, require special calculations, of which formulæ are given below in their respective places.

Low-level parallel-flow condensers. The air which is to be removed from this type of condenser is withdrawn along with the tail water, and is, therefore, practically at the same temperature, and its volume may be calculated as follows:

$$V_2 = \frac{V_1 P_1 (T_2 + 460)}{P_2 (T_4 + 460)}$$

where V_2 = volume of the air, in cu. ft., per lb. at temperature T_2.
P_1 = 14.7 lbs. per sq. in. pressure.
P_2 = Pressure of the air, or difference between total pressure in the condenser and the pressure of water-vapor at temperature T_2.
V_1 = 13.1 cu. ft.
T_2 = temperature of the tail water.
T_4 = 60° F.

This formula, as already shown, becomes on substitution:—

$$V_2 = \frac{0.37 (T_2 + 460)}{P_2}$$

The pressures used in condenser work being all below atmospheric pressure, and as temperature is such an important factor, it is found more convenient to take these pressures in inches of mercury rather than in pounds per sq. in., and the above formula then becomes transformed to:—

$$V_2 = \frac{0.37 (T_2 + 460) \times 2.04}{p_2} = \frac{0.755 (T_2 + 460)}{p_2}$$

The formula given above enables one to calculate the volume of 1 lb. of air at any temperature or pressure, but in order to obtain the pump displacement, it will be necessary to revise the above so as to give the volume of air and tail water per pound of steam, and as pump displacement is usually given as cubic inches per minute per 1 lb. of steam condensed per hour, a further alteration should be made in its construction.

$$D = \frac{0.755 (t + 460) \times (k + m) \times 1728}{P_2 \times 60} + n.$$

$$= \frac{21.8 (t + 460) \times (k + m)}{p_2} + n.$$

where D = Pump displacement, in cubic inches per minute per 1 lb. of steam condensed per hour.
t = temperature of tail water in deg. F.
P_2 = Pressure of the air (see above).
k = a constant, for type of apparatus. See Table 1.
$m = W \times 0.0001$ or $\dfrac{\text{lbs. of injection} \times 0.0001}{\text{lbs. of steam}}$
$n = (W + 1) \times 0.462$ = volume of tail-water.
W = weight of injection in pounds per 1 lb. of steam condensed per hour.

The curves given in Fig. 1 are plotted from this formula, tail water being taken at 10° below temperature proper to vacuum; injection water quantities are also given in the dotted curves. The values obtained from these curves are, of course, minimum values, and should be increased according to the designer's experience, and for the particular type of pump employed; for those unused to this type of work, the writer suggests an increase of 10 per cent as being quite sufficient to meet all contingencies.

Barometric condensers, or low-level counter-current apparatus. In this type the air is withdrawn at a point, either above or very little below the injection-water inlet, and is therefore removed at, or almost at, the temperature of the injection. The air pump deals with air only, and as this air is cooler, and therefore denser, the pump is necessarily smaller than the wet type of similar condensing capacity.

The formula giving injection water quantity is similar to that given previously, excepting that the temperature of the tail water is taken 5° below temperature proper to vacuum.

The temperature of the air is taken here as being 2° above that of the injection water, and this has been added to the absolute temperature value in the formula:

$$D = \frac{0.755\ (t + 462) \times (k + m) \times 1728}{P_2 \times 60}$$

$$= \frac{21.8\ (t + 462) \times (k + m)}{P_2}$$

where the symbols have the same meaning as in the previous formula, except t, which in this case is the temperature of the injection water.

The curves given in Fig. 2 are plotted from the above formula, and, as before, are, of course, minimum values. It will be noticed that a vacuum of 28 in. or over requires very large pump capacity, when the injection exceeds 70° F., and as this temperature is generally lower than the usual for tropical countries, it is very rare to find apparatus designed for such high vacua when intended for such localities.

In actual practice, a small portion of the air is carried out in the tail water, but it is safer, as a rule, to neglect this quantity.

Surface condensers. For this type of condenser very different conditions exist; the steam is condensed without coming into actual contact with the injection or circulating water, and the quantity of air to be dealt with is correspondingly reduced.

Most surface condensers are designed for counter flow, as this enables the circulating water to be used to the greatest advantage, and also allows the lowest possible temperature of the condensate being obtained.

There is a great deal in the design of surface condenser plant which depends upon special conditions, and as this is beyond the scope of the present article, the writer offers the curves in Fig. 3 as being only a guide, as it is almost impossible to give values which would suit all conditions.

The curves given are calculated on the assumption that the injection water is raised to a temperature 5° below that due to the vacuum, and that the condensate is cooled to 5° above the injection or circulating-water-inlet temperature.

$$V = \frac{21.8\ (t + 460) \times k}{P_2} + n_2$$

where V = displacement of vacuum pump in cubic inches per minute per 1 lb. of steam condensed per hour.

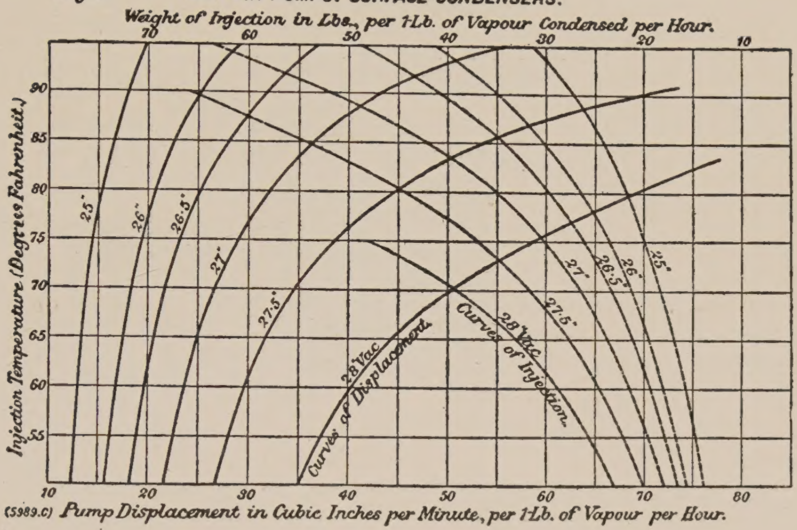
P_2 = pressure of the air (see above).

k = a constant, see Table 1.

n_2 = volume in cubic inches per minute of 1 lb. of condensed steam = 0.462.

t = injection temperature + 5°.

Fig. 3. WET-AIR PUMPS. SURFACE-CONDENSERS.



(5989.c)

In the curves, k has been taken as 0.0048, which is the value for triple-effect evaporators, and the displacements given by these curves must be multiplied by the co-efficients given in Table 2, if any other grouping of apparatus is required.

TABLE 1.—VALUES OF "K" $= \frac{\text{AIR}}{\text{STEAM}}$ IN POUNDS PER HOUR.

Type of apparatus.	"k"
Single effect	0.0044
Double effect	0.0046
Triple effect	0.0048
Quadruple effect	0.0059
Quintuple effect	0.0062

TABLE 2.—CO-EFFICIENTS FOR CORRECTING DISPLACEMENT GIVEN IN CURVES, FOR GROUPINGS OTHER THAN TRIPLE EFFECT.

Type of apparatus.	Co-efficient.
Single effect	0.917
Double effect	0.958
Triple effect	1.000
Quadruple effect	1.23
Quintuple effect	1.29

The word "air" used in many places throughout the text is intended to cover all incondensible gases.

The writer has not intended to give a thorough scientific reasoning, nor to make allowances for all the minute phenomena connected with this subject; such scientific, or, one should say, academic treatment is certainly desirable in dealing with research work, or in training students, but the errors caused by the omission of these refinements in the formula are so small as to be negligible, and as the points for the curves were all obtained by slide-rule aid, such differences have no doubt been fully covered by the method of taking the next higher even figure.

[W. R. M.]

SUGAR PRICES*

Ended February 15, 1921.

	96° Centrifugals		Beets	
	Per Lb.	Per Ton.	Per Lb.	Per Ton.
Feb. 2, 1921	4.485¢	$ 89.70		
" 3	4.51	90.20	No quotation.	
" 4	4.64	92.80		
" 8	4.89	97.80		
" 10	5.015	100.30		
" 11	5.2867	105.734		
" 14	6.02	120.40		
" 15	5.765	115.30		

* In order to fit in with our time of going to press, the sugar prices are here given for the first half of February. Hereafter, the period covered will be from the middle of one month to the middle of the next.

[D. A. M.]